D. NARAHARA* & T. PULLAIAH*: **Embryological investigations in *Amaranthus mangostanus* Linn.**

D. ナラハラ*・T. プライア*: ヒユの胚学的研究

Studies in the embryology of Amaranthaceae date back to the previous century. Hofmeister (1859) studied a few aspects of female gametophyte of some members of Amaranthaceae, while Braun (1859) reported polyembryony in *Celosia*. Savina (1983) has recently reviewed the embryology of the family Amaranthaceae. The genus *Amaranthus* consists of 60 species which are distributed both in the tropical and temperate regions (Willis 1973). Embryological studies in this genus are quite meagre. Souèges (1937a, b) reported Chenopodiad type of embryo development in *Amaranthus caudatus* and *A. retroflexus*. Kajale (1940) studied the embryology of *A. viridis* while Sebastian & Deshpande (1974) gave an account of development of male and female gametophytes in *A. leucocarpus*. A review of previous literature reveals that the embryology of *Amaranthus mangostanus* Linn. has not been worked out and hence the present investigation has been undertaken.

Material and methods Flowers at different stages of development were collected by the senior author from plants growing in the Sri Krishnadevaraya University campus and fixed in formalin-acetic-alcohol (F. A. A). Customary methods were followed for clearing and embedding the material. Sections were cut at a thickness of 5–7 μm and stained in Delafield's haematoxylin. Voucher specimen no. DN 1266 has been deposited in the Herbarium of Sri Krishnadevaraya University, Anantapur and Madras Herbarium, Coimbatore (MH).

Observations Microsporangium, microsporogenesis and male gametophyte. The anthers are tetrasporangiate (Fig. 1A). The male archesporium is hypodermal and consists of 5–7 cells in longitudinal section (Fig. 1B), and 2 to 3 cells in transverse section. The archesporial cells undergo periclinal divisions resulting in primary parietal cells and primary sporogenous cells. The primary parietal cells divide periclinally forming two parietal layers of which the outer functions as the endothecium, while the inner divides periclinally forming

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* Department of Bio-Sciences, Sri Krishnadevaraya University, Anantapur 515 003, A. P. India.

tapetum and middle layer (Fig. 1C–E). This type of anther wall development, according to Davis (1966), is known as Monocotyledonous type. The anther wall thus consists of four layers including the epidermis and all the four layers are seen even at the one-nucleate pollen grain stage (Fig. 1F).

The cells of the epidermis persist even at maturity (Fig. 1G). The hypodermis develops fibrous thickenings forming fibrous endothecium (Fig. 1G). The middle layer gets crushed and degenerated during the male gametogenesis. Anther tapetum is of the glandular type. Tapetal cells are completely absorbed by the growing pollen grains and no trace of the tapetum is left at maturity (Fig. 1D, G).

The primary sporogenous cells undergo mitotic divisions in all planes resulting in an extensive mass of pollen mother cells (Fig. 1D, E). Pollen mother cells undergo meiotic divisions resulting in tetrahedral (Fig. 1H) and isobilateral pollen tetrads. The microspore after its release from the tetrad shows a large vacuole while the nucleus and the cytoplasm are pushed towards one side. The mature pollen grains are 3-celled with 8 to 10 germ pores.

Ovary and ovule. The ovary is unicarpellary and unilocular with a single basal ovule. The ovule is bitegmic and crassinucellate. It arises as a papillate outgrowth (Fig. 2A) from the base of the ovary. During megasporogenesis, due to unequal growth, the ovule acquires anatropous condition (Fig. 2B). After fertilization the ovule becomes amphitropous in which the embryo sac becomes horse-shoe-shaped (Fig. 2C). Both inner and outer integuments are two-layered, but the inner becomes more massive at the micropylar end where it forms the micropyle. The integuments are seperated at the chalazal end by an air space (Fig. 2B, C).

The female archesporial cell is hypodermal and single-celled. It cuts off a parietal cell towards the micropyle and a sporogenous cell towards the chalazal side (Fig. 2A). The parietal cell first undergoes periclinal and then anticlinal divisions forming parietal tissue making the sporogenous cell deep seated. The sporogenous cells enlarges and functions as a megaspore mother cell. It undergoes meiotic divisions resulting in linear tetrad of megaspores (Fig. 2E). Only the chalazal megaspore is functional (Fig. 2E). It undergoes three nuclear divisions resulting in an 8-nucleate embryo sac of the *Polygonum* type (Fig. 2F–H). The egg apparatus consists of two synergids and one egg cell. The polar nuclei fuse in the middle of the embryo sac forming secondary nucleus.

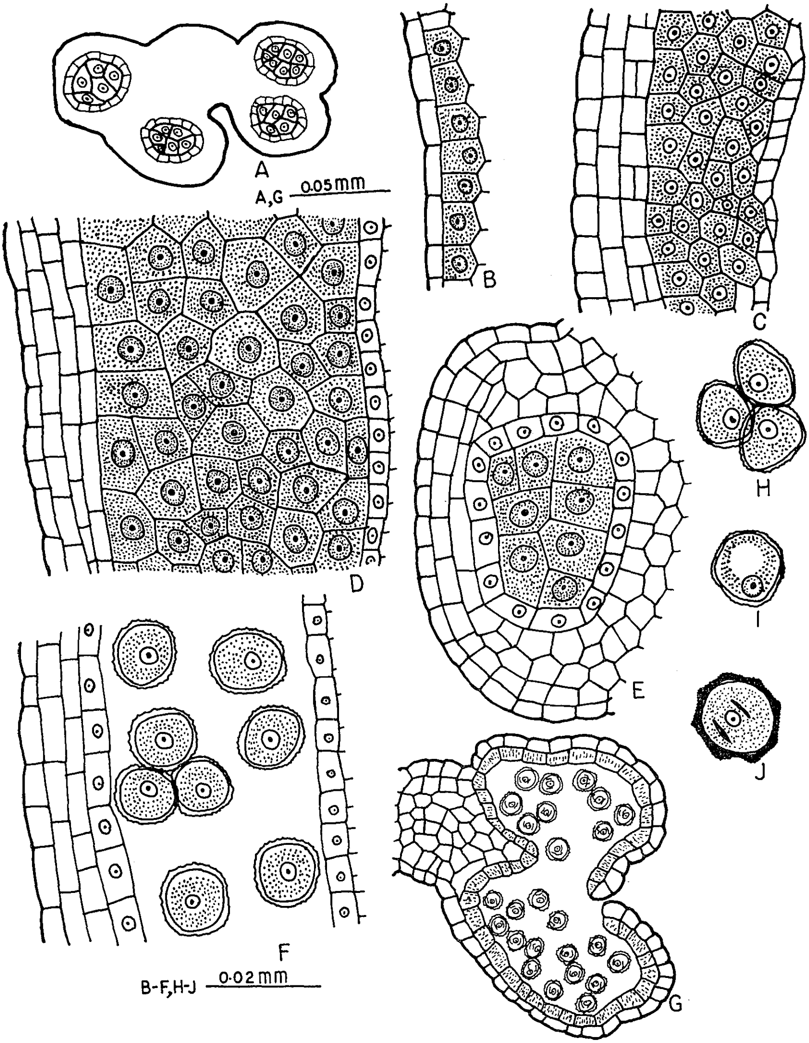

Fig. 1. *Amaranthus mangostanus.* A. Transverse section of tetrasporangiate anther. B-D. Longitudinal section of anther lobes showing wall development. E. Transverse section of anther lobe showing wall layers and pollen mother cells. F. Longitudinal section of anther lobe showing wall layers and one-nucleate pollen grains. G. Transverse section of mature anther. H. Pollen tetrad. I-J. 1-nucleate and 3-celled pollen grains respectively.

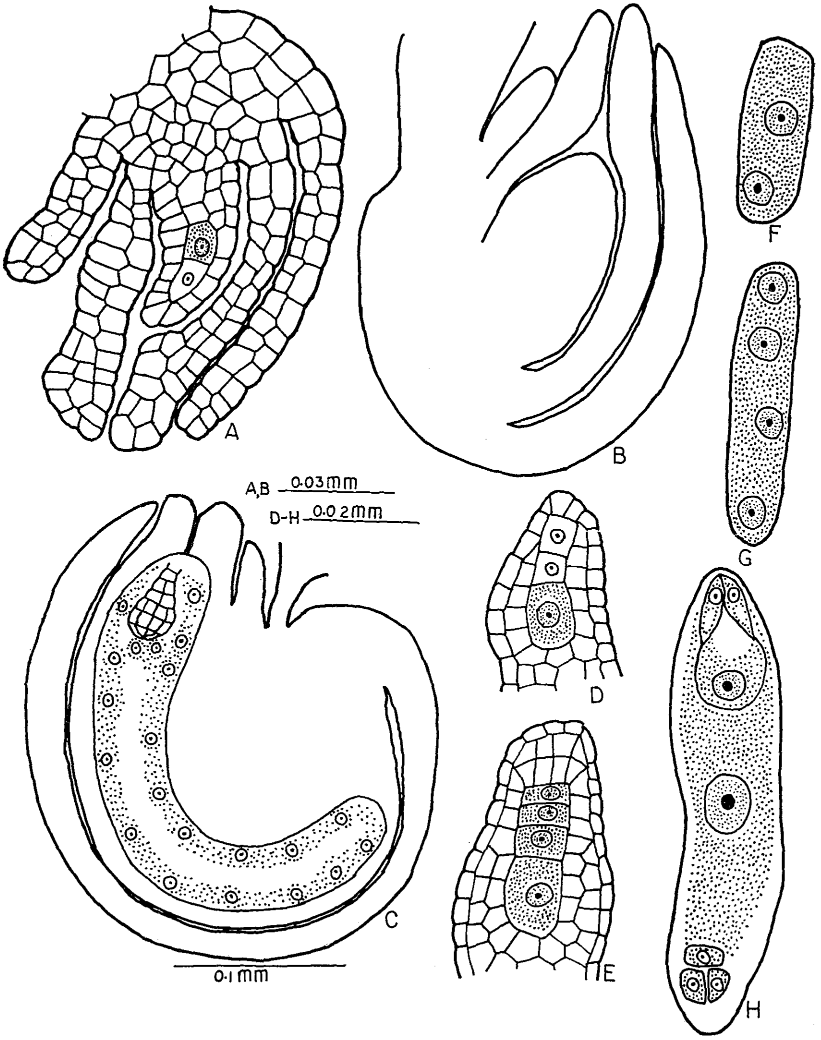

Fig. 2. *Amaranthus mangostanus.* A–C. Development of ovule. D. Megaspore mother cell and two parietal cells. E. Megaspore tetrad. F–H. Development of embryo sac.

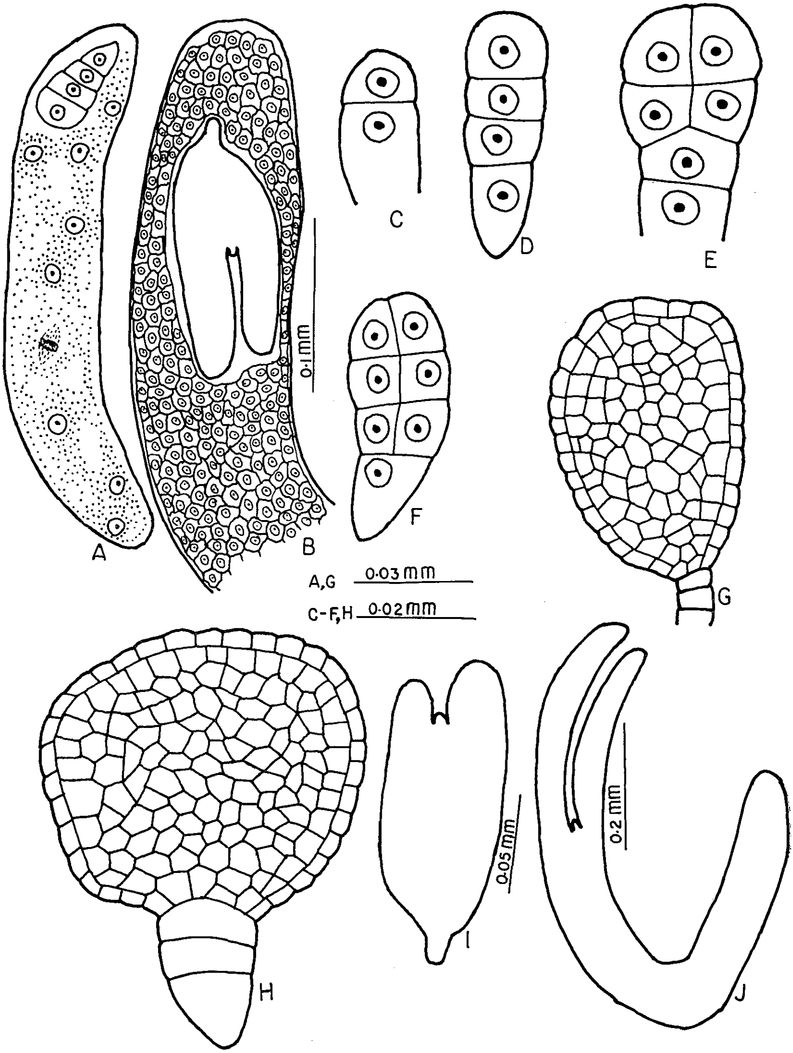

Fig. 3. *Amaranthus mangostanus*. A, B. Stages in the development of endosperm. C–J. Stages in the development of embryo.

The antipodal cells are ephemeral (Fig. 2H).

Fertilization, endosperm and embryo. The entry of pollen tube is porogamous. Fertilization is normal. Endosperm development is of the Nuclear type. The primary endosperm nucleus divides earlier than the zygote and divisions are free nuclear (Fig. 3A). The nuclei are distributed at the periphery (Fig. 2C). Free nuclear divisions continue till the initiation of cotyledons. Wall formation in the endosperm starts at the micropylar end and extends towards the chalazal side (Fig. 3B). The endosperm becomes cellular completely. The growing embryo consumes most of the endosperm leaving one or two layers in the mature seed.

The zygote undergoes a transverse division resulting in a terminal cell *ca* and a basal cell *cb* (Fig. 3C). Both the cells undergo another transverse division resulting in four-celled linear proembryo (Fig. 3D). The derivatives of the cell *ca* are designated as *l* and *l′* whereas the derivatives of the *cb* are designated as *m* and *ci*. The tiers *l*, *l′* and *m* undergo two vertical divisions at right angles to each other forming quadrants in each tier. The tier *ci* undergoes a transverse division resulting in *n* and *n′* (Fig. 3E, F). During further development the tier *l* gives rise to the stem tip and cotyledons, *l′* and *m* to the hypocotyl and a part of the *ci* to the root tip and root cap (Fig. 3G–J). The remaining part of *ci* forms a suspensor of three to four cells (Fig. 4H). The four-celled proembryo is linear and both the cells *ca* and *cb* contribute to the development of the embryo proper and hence the embryo development conforms to the Chenopodiad type (Johansen 1950). The mature embryo is curved (Fig. 3J).

Perisperm. As the embryo sac elongates like a horse-shoe, it encloses the central part of the nucellus which persists in the mature seed as perisperm.

Discussion The anther in the family Amaranthaceae is tetrasporangiate in all the members investigated so far except in *Alternanthera sessilis* where bisporangiate anthers are met with (Kajale 1940). The male archesporium consists of 2–4 cells in transverse section and 5–7 cells in longitudinal section, a condition reported in most members of the family. However, in *Digera arvensis* (Puri & Singh 1935) and *Pupalia lappacea* (Kajale 1940) there is only a single vertical row.

The ovule in the family Amaranthaceae has been described variously by different embryologists. It is described as anacampylotropous in *Celosia argentea*, *Amaranthus viridis, Cyathula tomentosa, Pupalia lappacea* (Kajale 1940), *Aerva tomentosa* (Sachar & Murgai 1959), campylotropous in *Allmannia nodiflora* (Kajale 1940) and *Celosia cristata* (Pal 1968), amphitropous in *Psilostachys sericea* (Bakshi 1952) and *Amaranthus leucocarpus* (Sebastian & Deshpande 1974). In the present study the ovule is found to be amphitropous. Since the embryo sac and embryo are curved in all the members of Amaranthaceae the ovules must have been designated as amphitropous. While classifying the ovules, Maheshwari (1950) says (p. 54) "— when the curvature is more pronounced and also affects the embryo sac, so that the latter becomes bent like a horse-shoe as in Alismataceae, Butomaceae and Centrospermales the ovule is called amphitropous". Since all the members of Amaranthaceae so far investigated show a curved embryo which must have arisen due to curved embryo sac, the ovules have to be designated as amphitropous. Hence the statements of Kajale (1940), Sachar & Murgai (1959) and Pal (1968) seem to be doubtful.

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ヒユの花の胞原細胞は2-3層からなり，それが胞子形成組織と側壁細胞層に分化する。側壁細胞層は内皮 (endothecium)，中間層，タペータムに分かれる。後2者は花粉形成と共に消失し吸収される。内皮は繊維質になる。タペータムの消失過程はグラニュラル型である。花粉は放出時には3細胞からなり8-10個の発芽孔がある。胚珠はカラザの部分までかなりのすきまのある2枚の珠皮をもち，珠孔は内珠皮から作られる。珠心の中に1個の胚嚢母細胞ができ，その外側の細胞は分裂して多層になる。胚嚢形成はタデ型である。反足細胞は3細胞からなるが短命である。受精前の胚珠は半倒生であるが，受精後著しく湾曲して馬蹄形となり，中央に珠心の一部を取り囲む。この珠心の部分は後に外胚乳となる。胚乳形成は多核型である。胚形成はヨハンセンのアカザ型に相当する。以上の花粉，胚乳，胚形成の過程はアカザ科の今までの報告とほぼ一致する。

□伊藤浩司・日野間彰（編）：**北海道高等植物目録 I，シダ植物・裸子植物** (Ito, K. & A. Hinoma: Check list of higher plants in Hokkaido I. Pteridophyta. Gymnospermae) 73pp. 1985. たくぎん総合研究所，札幌. ¥2000. 北海道の自生及び栽培植物の目録で，学名とその異名，和名とその異名が載せられ，自生のものには支庁名でその産地が記されている。北海道全体の植物の総目録として便利である。この目録は編者の見解のもとに作られたには違いないが，今後の研究の基礎資料として，今までの主な文献をコンピューターで処理し，それに編者の知見を加えて作られたもので，種の範囲や学名の選択には編者の見解が入るにしても，それは極力おさえられている。北海道は最近でもまだ新植物が発見される状態であり，隣接地域のものとの比較も充分とはいえないので，今後の研究の基礎としての貴重な労作である。コンピューターに入れるのに利用した総合的な文献以外に殆んど個別的な文献がのせてないが，基礎資料ということだし，学名の出典をさがすのに苦労するものもあるので，全部でなくても学名ごとに出典を入れておいてくれるとさらに役立つものとなるであろう。書店にあまり出ないだろうと思うので発行所をあてげおく。たくぎん総合研究所　〒060 札幌市中央区大通西3丁目6番地 道新ビル。

（山崎　敬）